Adaptive Delegation Interfaces (ADI) for Improved Situation Awareness and Reduction of Workload in Controlling Multiple Unmanned Vehicles (UV)

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Abstract

A design is proposed for an Adaptive Delegation Interface (ADI) to support human operators in controlling multiple UVs. The ADI can enhance system performance by (1) providing the operator flexibility to allocate UV automation in response to changes in workload and task complexity; and (2) adaptively selecting information to support instantaneous task needs. The proposed project will develop new ADI concepts and evaluate them experimentally in a realistic simulation environment. This paper describes the concept of ADI, the current interface design, and its integration within a military simulation environment.

Introduction

Unmanned vehicles and other robotic systems are being introduced into Army systems to extend manned capabilities and act as "force multipliers" (Barnes, Parasuraman & Cosenzo, in press; Cosenzo et al, 2006). Because of the resulting increase in the cognitive workload demands on the soldier, increasing levels of robot autonomy as well as adaptive

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automation aids may be required to enhance soldier and system performance. The resulting human-robot team represents a *mixed-initiative system* — an intermediate stage between the far-off goal of "full" robot autonomy and the unacceptable use of completely manual robotic teleoperation by the soldier.

Mixed-initiative systems can in principle yield significant benefits in terms of mission effectiveness. However, appropriate and sensitive metrics are needed for evaluating human-robot team performance in order to determine the appropriate levels of robot autonomy and automation that will lead to enhance system performance. This is because mixed initiative introduces a new and unique aspect to the psychology of team performance: the interaction of two cognitive systems -- human and autonomous or semi-autonomous unmanned robot. In addition to the critical performance factors associated with human teams -- which include information exchange, communication, supporting behavior and team leadership -- the mixed manned/unmanned team adds a number of challenging new dimensions. Foremost among these is the ability of the human team to predict, collaborate, and develop trust with unmanned systems that may sometimes exhibit fuzzy responses in unstructured and unpredictable environments.

Innovative ADI Concept

Miller and Parasuraman (2007) have proposed an innovative concept of adaptive human-automation interaction based on the concept of *delegation* – the concept is called Adaptive Delegation Interfaces, or ADI. Adaptive delegation interfaces are *adaptive* because they are responsive to context and user needs, and involve *delegation* in the same sense that a supervisor works with a human subordinate—the difference being that the

human uses an interface that allows for high-level communication with the automation in a common language.

The performance benefit of adaptive compared to static automation is well documented (Parasuraman et al., 2005). Delegation interfaces provide a methodology that allows operators to explicitly task automation at times of their choosing—that is, where the user is in charge of the adaptation. At present, however, there is only a small body of empirical research on human supervision of UVs, particularly with automation support.

Previous research has pointed to the general utility of delegation interfaces in allowing for effective supervisory control of multiple numbers of UVs and recent experimental work has partially validated the concept for a relatively simple multi-robot "capture the flag" task (Parasuraman et al., 2005). These results point to the potential for delegation interfaces to enhance mission effectiveness in several critical situations; for example: in multi-robot supervision by a single operator, or where an operator must time-share control of a robot with other essential operational tasks, for example while serving as a member of a tank crew.

However, the history of human-computer interaction design is replete with instances of interfaces that were initially thought to be beneficial but were inadequately tested, with the result that they were found to be plagued with subsequent problems (Schneiderman, 1993). It is therefore important that the potential drawbacks as well as the advantages of any new interface concept are also investigated, so that a balanced view can be drawn of its effectiveness and usability. Two potential problem areas are increased or unbalanced *mental workload*, which can be a feature of some automation designs (Parasuraman & Riley, 1997), and high *task switching* times. Accordingly, while the study results are

promising, the ADI concept needs further development as well as validation in tactically realistic scenarios before it can be applied in the design of operational battlefield systems. This research project is intended to accomplish those goals.

Proposed Research Approach

Previous work on interaction between humans and automated agents, including unmanned vehicles (UVs), has revealed both benefits and costs of automation for system performance (Parasuraman & Riley, 1997; Parasuraman et al., 2005; Sheridan & Parasuraman, 2006). Automation is clearly essential for the operation of many complex human-machine systems, including UVs and other robotic systems. But automation can also lead to novel problems such as increased workload and training requirements, impaired situation awareness and, when particular events co-occur in combination with poorly designed interfaces, accidents (Degani, 2004). Retaining the benefits of automation while minimizing its costs and hazards may require the interface between humans and robotic agents to be *adaptive* rather than fixed and static. The performance benefit of adaptive compared to static automation is well documented (Parasuraman et al., 2005). However, if adaptation is executed without user approval or knowledge, the cost of system unpredictability may outweigh the benefit that automation provides. What is needed is a method that allows operators to explicitly task automation at times of their choosing—that is, where the user is in charge of the adaptation. We have recently proposed a theory of adaptive human-automation interaction based on the concept of *delegation* (Miller & Parasuraman, 2007).

The key idea behind delegation is that the supervisor has flexibility in the use of automated support in supervising multiple UVs. The operator can delegate bigger,

coarser-grained tasks or smaller, more precise ones with more or less explicit instruction about their performance, depending on context and task demands. Delegation architectures seek to provide highly flexible methods for the human supervisor to declare goals and provide instructions and thereby choose how much or how little autonomy to give to automation, depending on context and the current situation. It is important to note that the communication between human and automated agents, while using a mutually understood "language", are nevertheless constrained by the specific doctrine, jargon, and tactics of the domain, and do not involve completely unconstrained communication as between two humans.

Figure 1 shows the ADI concept in a total system context. The Interface Controller selects the information display and automation mode, the Information Priority Selector determines what information the operator needs based on its value as calculated using the Task Decision Model, the Delegation Modes Library supplies the appropriate modes of control as determined by the human-robot Team Performance Assessment system and operator inputs. The ADI is *adaptive* because it is responsive to immediate context and user needs, and involves *delegation* because it allows the operator with the help of the system to task the robot at the appropriate level of automation.

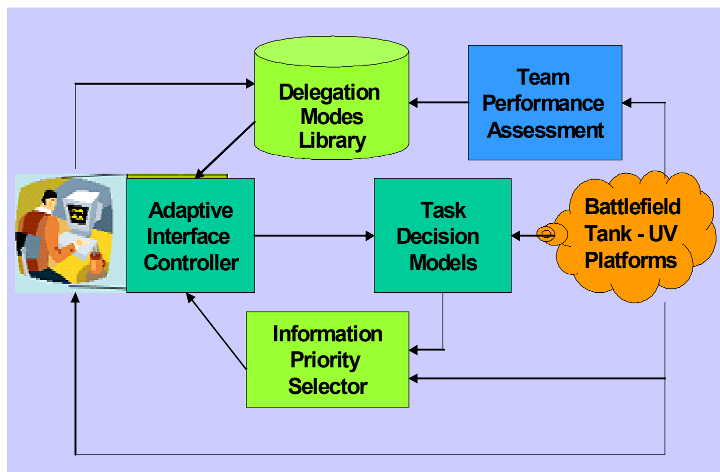

Figure 1. ADI in Total System Context

ADI Interface Design

We have designed the interface of the ADI based on common human factors principles that optimize situation awareness and task load for the operator (see Endsley et al., 2003). In addition, earlier interfaces to control robotic assets have inspired our design. Figure 2 shows the current interface of the ADI.

Figure 2. ADI Interface.

In the following we describe each component of the interface. Each display is designed with the concept of flexible delegation. The operator can work within the complete automation spectrum from maintaining a high-level overview and letting most of the automation do the work, to specifying plans and monitoring each of the assets individually.

Mission Planning & Execution.

Any mission begins with planning and therefore the operator can use this panel to specify his plan. We designed this display so operators can specify a plan at a very level of detail, or alternatively, provide the system with high level parameters and let the automation finish the rest of the plan. The operator has a choice between several mission templates, e.g., reconnaissance, surveillance, and IED seek & destroy. Each of these templates requires certain parameters to be specified by the operator while others can be handled by either the operator or the automation. When the operator is finished with his plan, he can execute. The display then turns into a monitoring panel which displays the high overview status of each robotic asset.

System Monitoring.

During a tactical mission, robotic assets require a degree of system monitoring. This panel shows an overview of the robotic unit status. Should a malfunction occur with these robotic assets, the operator has the ability to drill down into this display to investigate occurring problems. This display also shows how automation can be scaled for system monitoring. The operator can choose to merely monitor the high-level overview of the system and let robotic assets handle any system malfunctions or investigate a specific issue by drilling down into the display. This panel then allows for scalable situation awareness based on the operator’s needs and capabilities at a given moment during a mission.

Intelligence Gathering & Analysis

Robotic assets will collect sensor data throughout the mission that can be gathered and analyzed in this display. This data can include images, Infra-red sensor data, and live

video feed. The operator can again let the automation analyze the data and produce a list of potential targets and relevant information, or research the data himself and produce a list of potential targets and information. This information can then be used to adjust the plan for the robotic assets.

Communications

Communications are important for the operator in several ways. The operator should be able to receive commands from a commander or superior officer. Updates on the mission can also be relayed by the operator to superior officers through the communication display. In addition, robotic assets can send messages to the operator of various types including, but not limited to, status messages, target confirmation requests, and severe system failures. Future implementations of the ADI may also include the ability to converse with the robotic assets through this panel.

Courteous Intelligent Robotic Agent (CIRA)

The ADI is a comprehensive display. There is a risk of overloading the operator with too much information. We designed the Courteous Intelligent Robotic Agent to facilitate interaction with the robotic assets and to attract attention, if needed, to critical issues in the mission planning and execution, system monitoring, data gathering and analysis, and communications with the robotic assets. Three features make the CIRA a handy tool for an operator:

- The CIRA gives suggestions on the next course of action for the operator
- The CIRA alerts the operator to highly critical issues during a mission
- The CIRA shows the current stage of the mission
- The CIRA can be turned on or off based on the operator preference

Simulation Environment

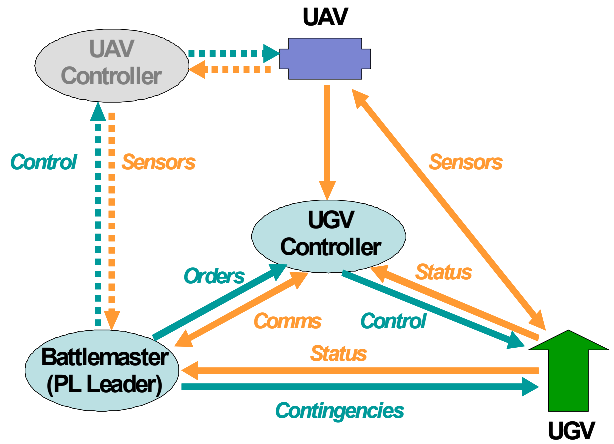

Figure 3. Command and Control Structure

The ADI Interface will be integrated with our Mixed Initiative Performance Assessment System (MITPAS) (Freedy et al, 2006). Figure 3 shows the command and control configuration for our simulation environment and experimental studies. The Battlemaster, who plays the platoon leader (see below), will also be in charge of the experimental procedures, the progress of the scenario, and communication with the Unmanned Ground Vehicle controller, who is the actual experimental participant. In our planned scenario, the UGV Controller will be able to control several UGVs simultaneously using the ADI.

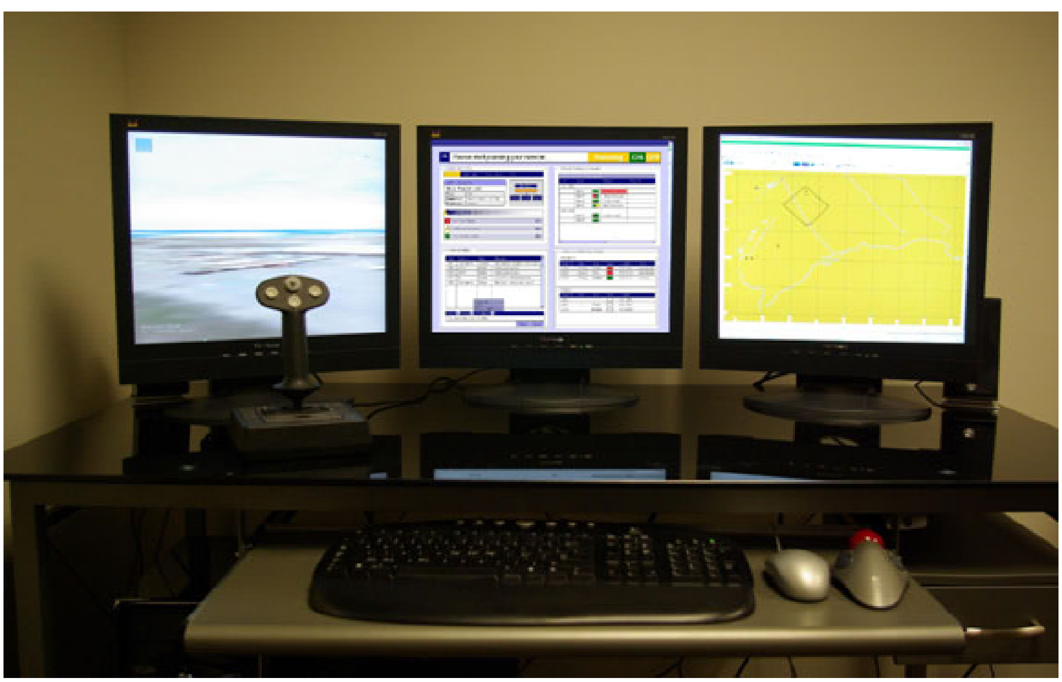

Figure 4. MITPAS UGV Station with ADI.

The command and control stations used by the Battlemaster and the UGV controller are very similar. This station as shown in Figure 4 is comprised of a tactical situation map, the ADI, and a UGV video feed represented on three 19 inch monitors. The operator uses a keyboard, track-ball mouse, and joystick to control the system.

The middle screen shows the ADI. The operator can manage all his tasks from this display. The tactical situation map, generated by the military simulator OOS on the right monitor, shows the UGVs' geographic positions and also gives an overview of the entire tactical situation. On the left monitor, video feeds from each UGV are available if the operator wishes to obtain a closer of the situation.

Tactical Scenario

Currently we have developed one scalable robotic team behavior -- search for IEDs. We have developed a Route Reconnaissance and Obstacle Clearance (RROC) based on this team behavior (see Figure 5) that spans the anticipated range of maneuver control and contingency handling events. The mission is to ensure in an urban environment that the area is safe for an approaching convoy by identifying and eliminating dangerous (IEDs), objects and surrounding enemies. The available UV resources are two TALON ground vehicles and a surveillance helicopter working as a team with one human operator. In brief, the robot-human team is part of a reconnaissance platoon. Its mission to ensure that a specific terrain area is safe by detecting a mined car and clearing it as well as potentially eliminating all surrounding enemy forces. To do this, the team has to coordinate the actions of the UAV and UGVs, move the UGVs to a checkpoint where they can commence mine clearing operations until the mine is neutralized as well as targeting and firing on enemy forces until they are destroyed.

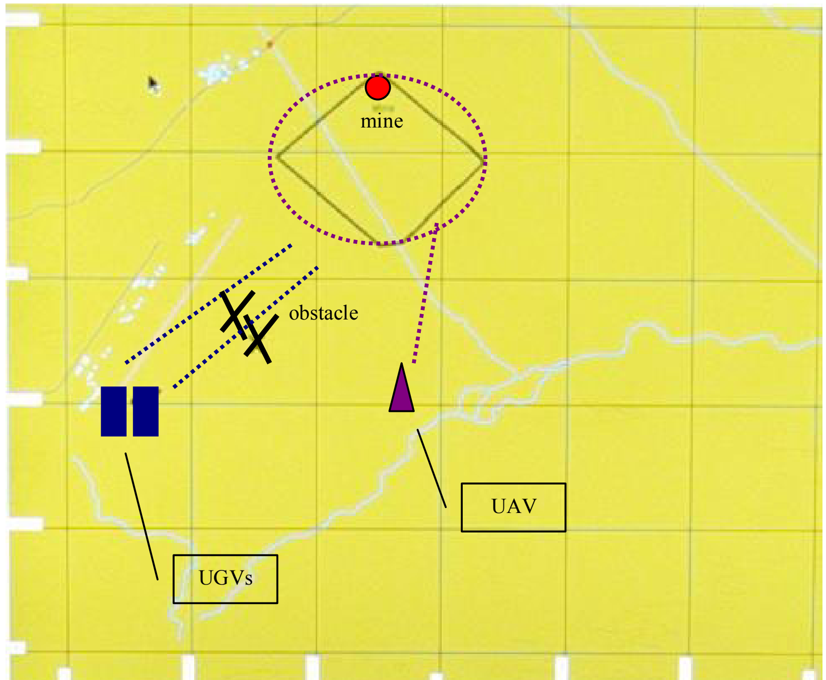

Figure 5. Scenario with Several Robots Conducting a Reconnaissance Mission

The team has to monitor and evaluate the maneuvering, IED clearing and autonomous targeting and firing capabilities of the UVs and take over control of the vehicles if decrements in these autonomous processes would cause a mission delay or a complete failure; e.g., firing competency can be enhanced by moving the Fire Cover UGV closer to the enemy. The team task will be specified as an event-based scenario containing planned events which will evoke re-planning by the team due to unpredictable contingencies: A number of contingencies typical of future robot systems will be inserted. These include:

- Obstacle in the road
- Communication loss
- Mechanical failure

We plan to create additional and more scalable robot team behaviors to support control of the human operator through the ADI.

Conclusion

As robotic assets become more autonomous the role of robotic operators will shift from physically controlling one robot to managing a robotic team with numerous assets. We believe that the adaptive delegation interface (ADI) will provide robotic operators with the capabilities needed to effectively manage several robotic assets simultaneously in dynamic and uncertain environments. New interfaces must allow for flexible, scalable, and automated control of robotic assets to optimize human-robot team performance. The adaptive delegation interface incorporates both adaptive and adaptable automation to address these needs. With this interface, operators can scale, monitor and adjust their missions based on preference and work load. Automation can be activated or deactivated based on mission events, mission history, and performance by the operator. Future experiments will examine the effects of the ADI on the control of multiple robotic assets and overall team performance and mission effectiveness.

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